US009512684B2

(12) **United States Patent**
Khaparde et al.

(10) **Patent No.: US 9,512,684 B2**
(45) **Date of Patent: Dec. 6, 2016**

(54) **SHOCK TOOL FOR DRILLSTRING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 235 days.

(21) Appl. No.: **14/382,436**

(22) PCT Filed: **Nov. 22, 2013**

(86) PCT No.: **PCT/US2013/071461**
§ 371 (c)(1),
(2) Date: **Sep. 2, 2014**

(87) PCT Pub. No.: **WO2015/076825**
PCT Pub. Date: **May 28, 2015**

(65) **Prior Publication Data**
US 2016/0230479 A1 Aug. 11, 2016

(51) **Int. Cl.**
E21B 17/07 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 17/07*** (2013.01); *E21B 17/073* (2013.01)

(58) **Field of Classification Search**
CPC E21B 17/07; E21B 1/073
See application file for complete search history.

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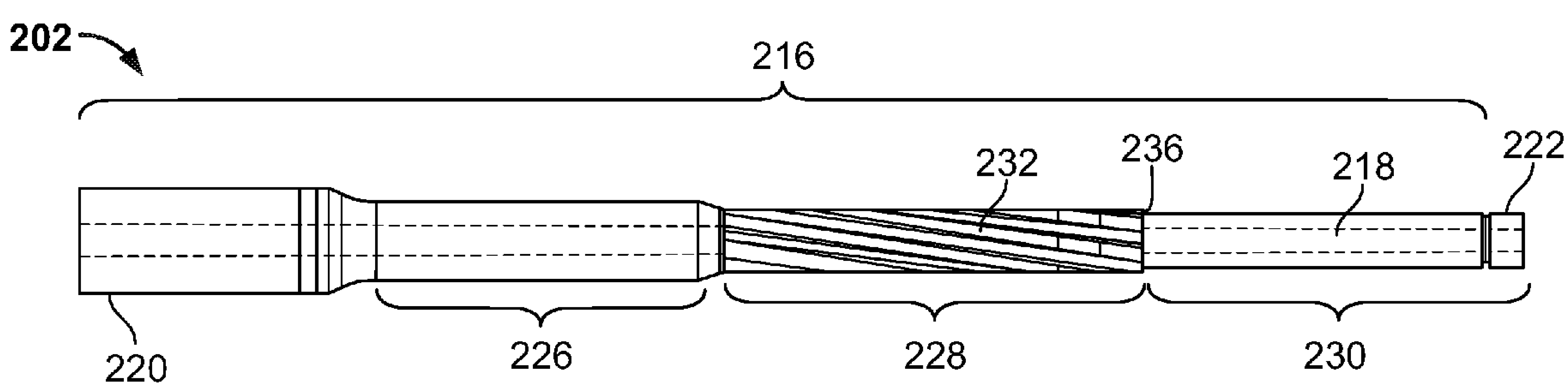
(57) **ABSTRACT**

A shock tool for a drill string includes an outer tubular housing having female multi-spiral helical spline grooves disposed on an interior surface of the housing, and an inner tubular mandrel having a portion of an exterior circumferential surface with mating male multi-spiral helical splines. The inner tubular mandrel is telescopically and rotationally received in the outer tubular housing with the male splines received in the female spline grooves of the housing.

21 Claims, 5 Drawing Sheets



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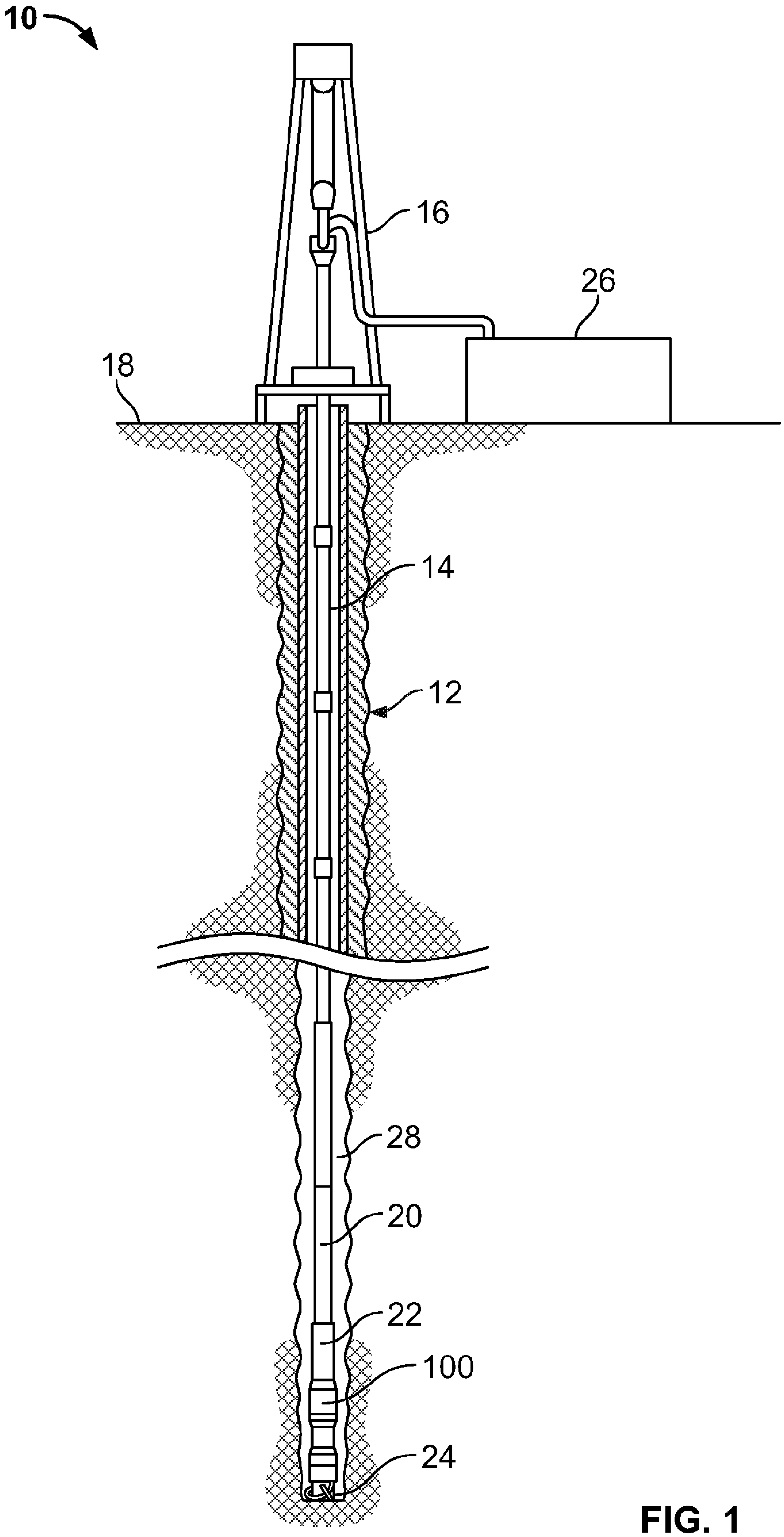


FIG. 1

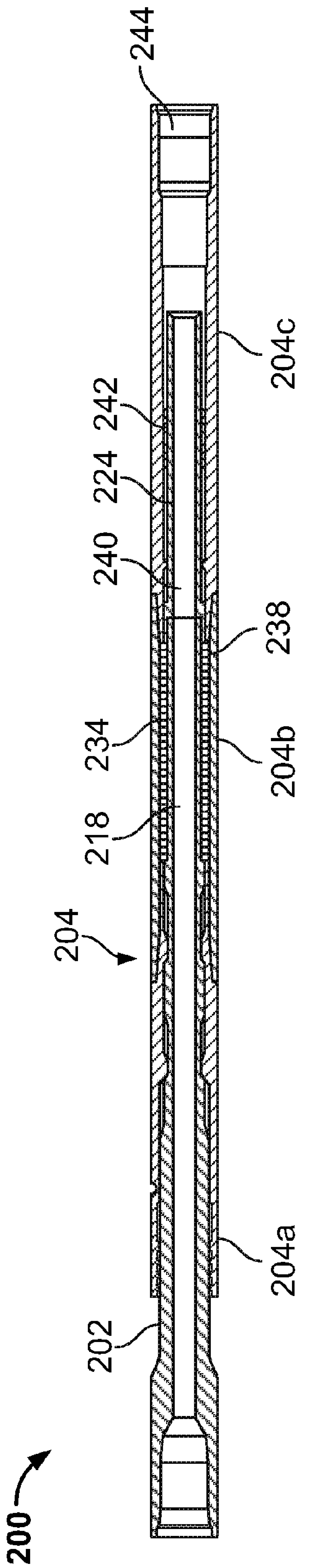
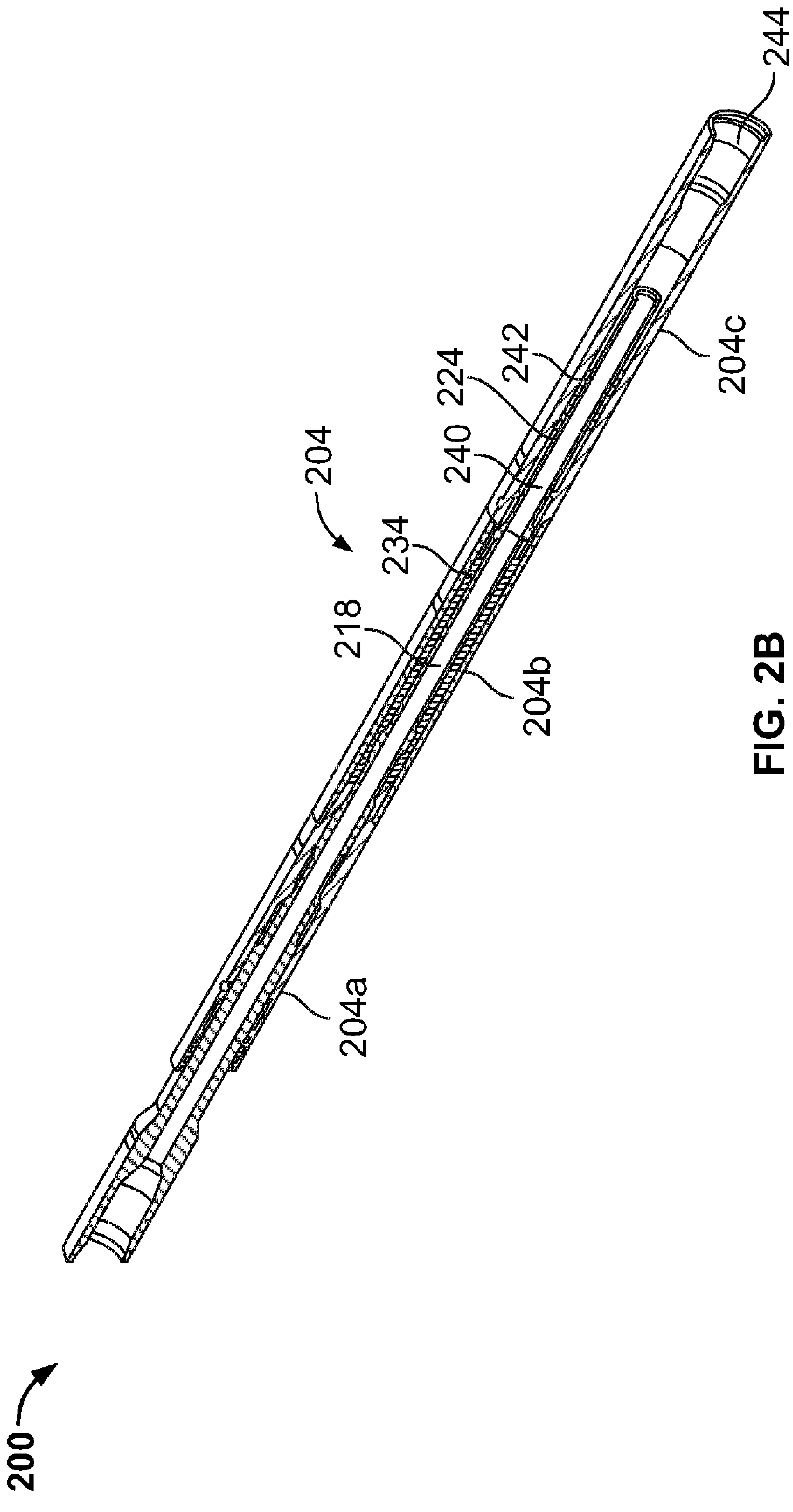

244
204c
242
224
240
238
234
204b
218
204
204a
202
200

FIG. 2A


244
204c
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200

FIG. 2B

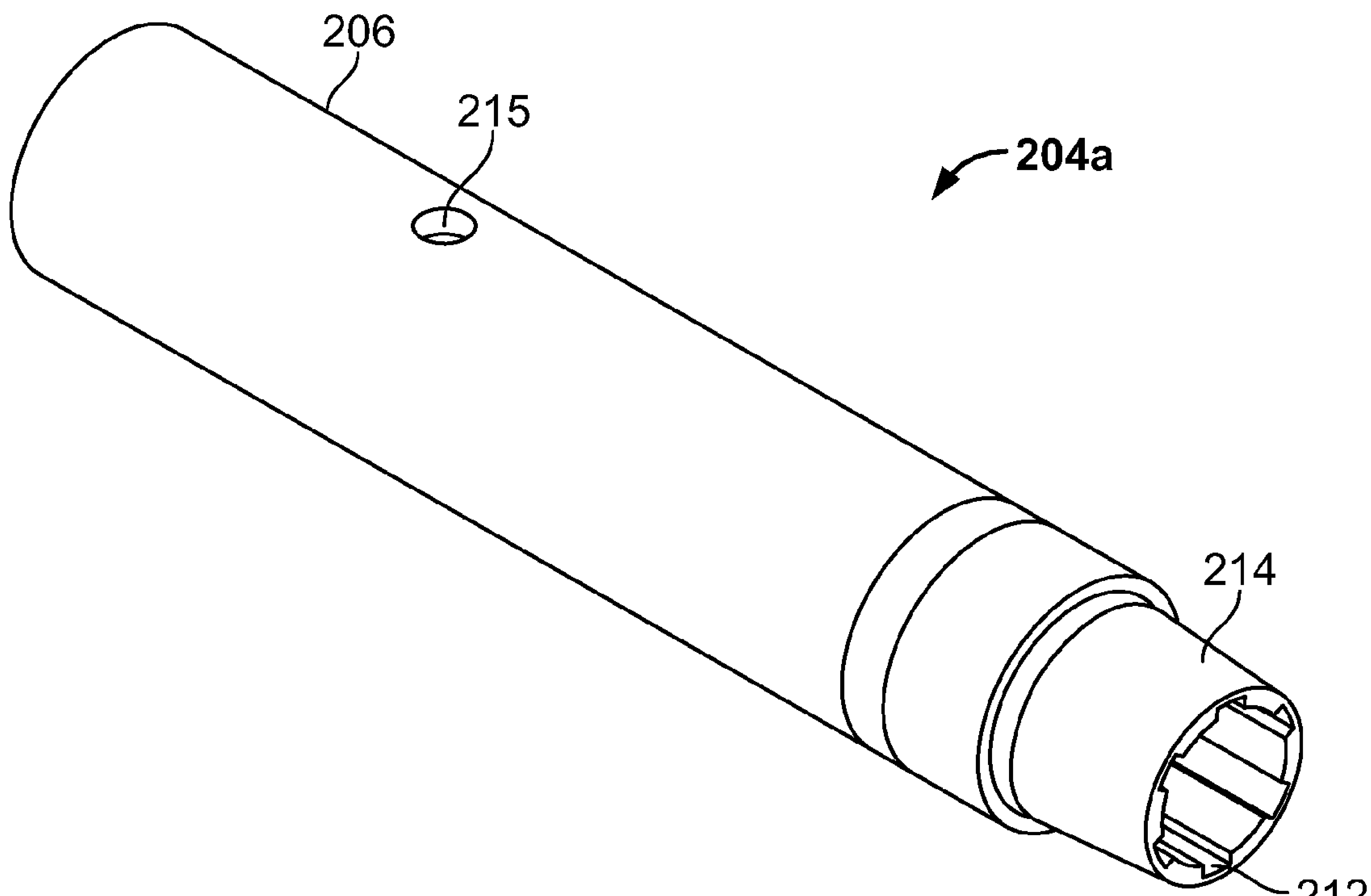


FIG. 3A

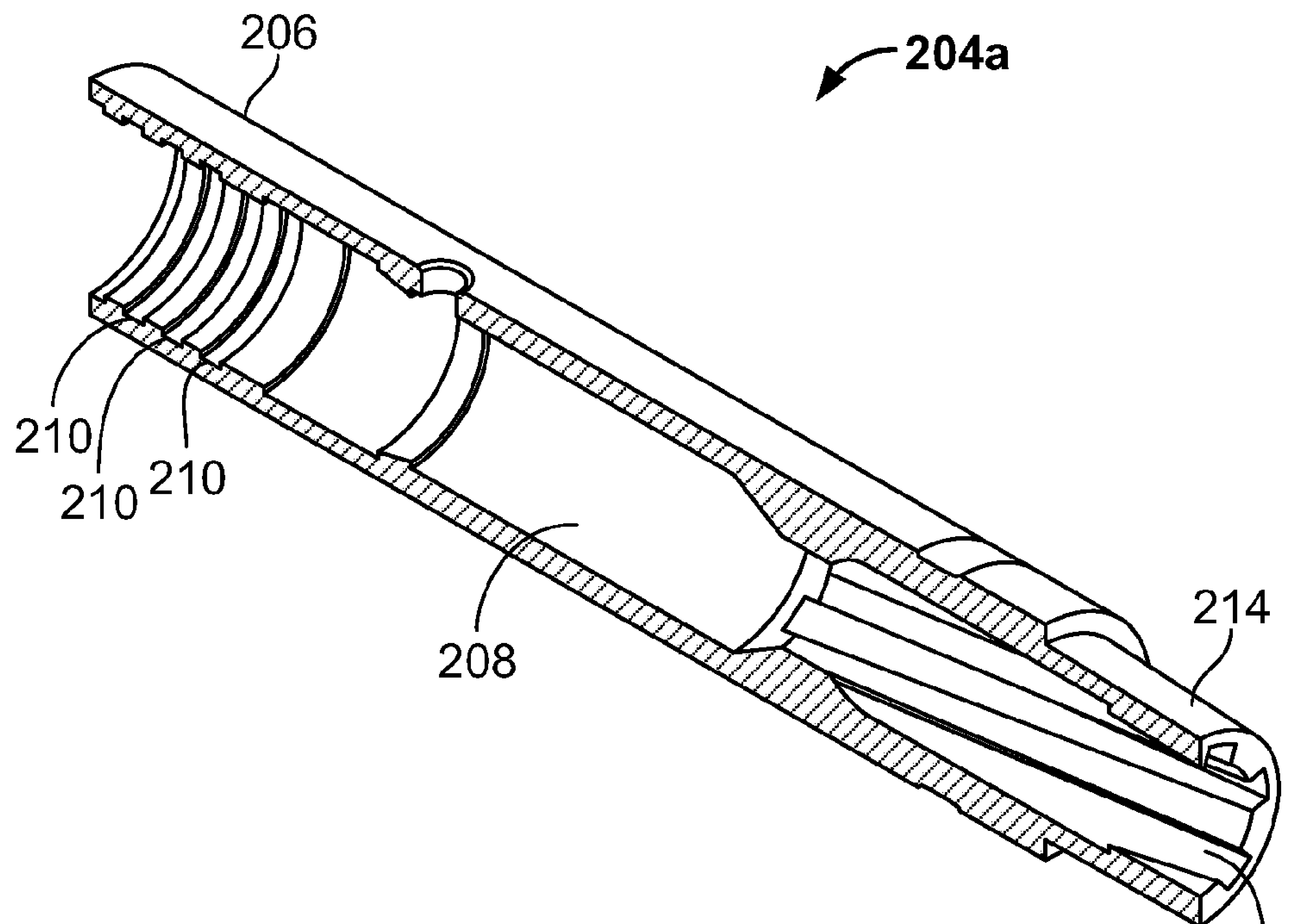


FIG. 3B

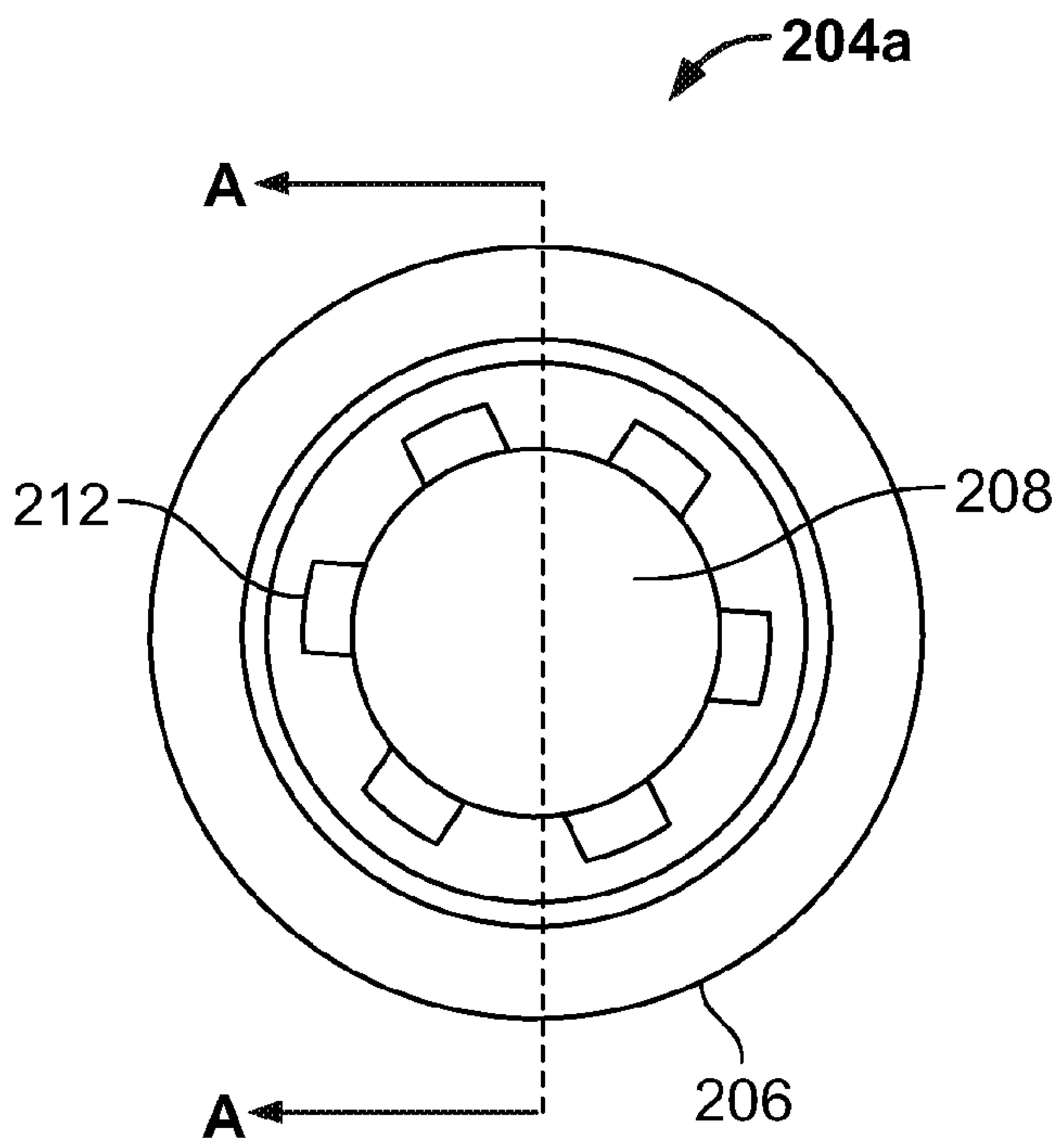


FIG. 3C

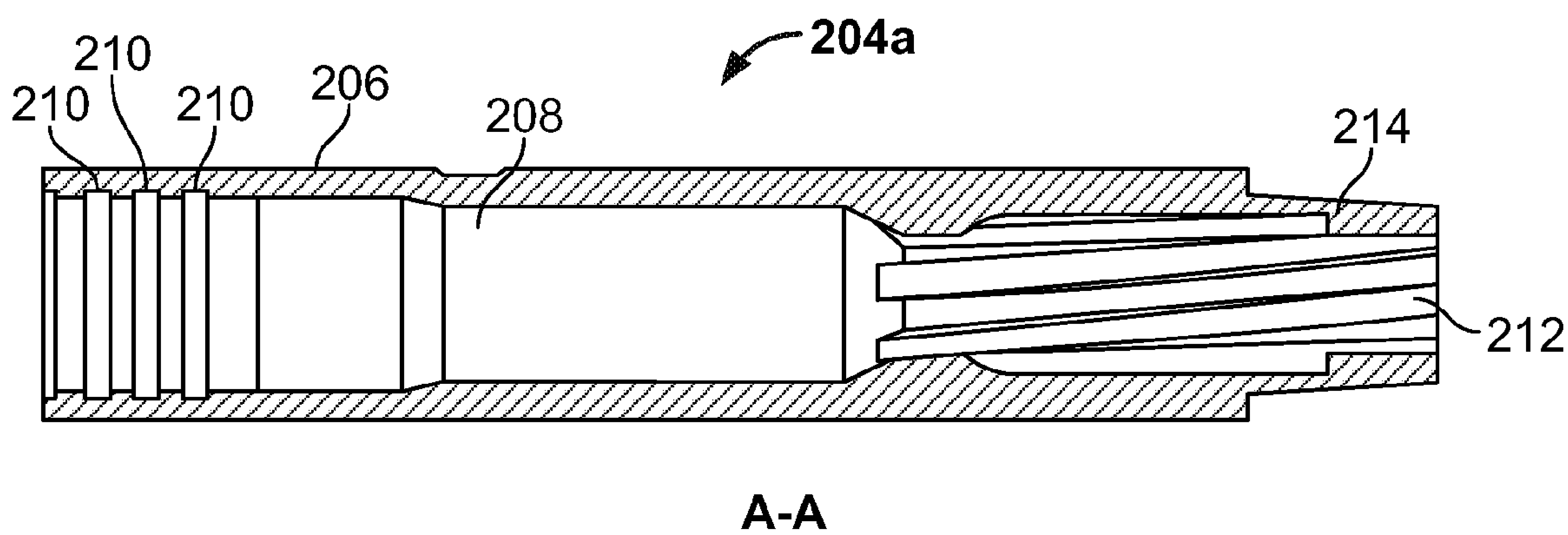
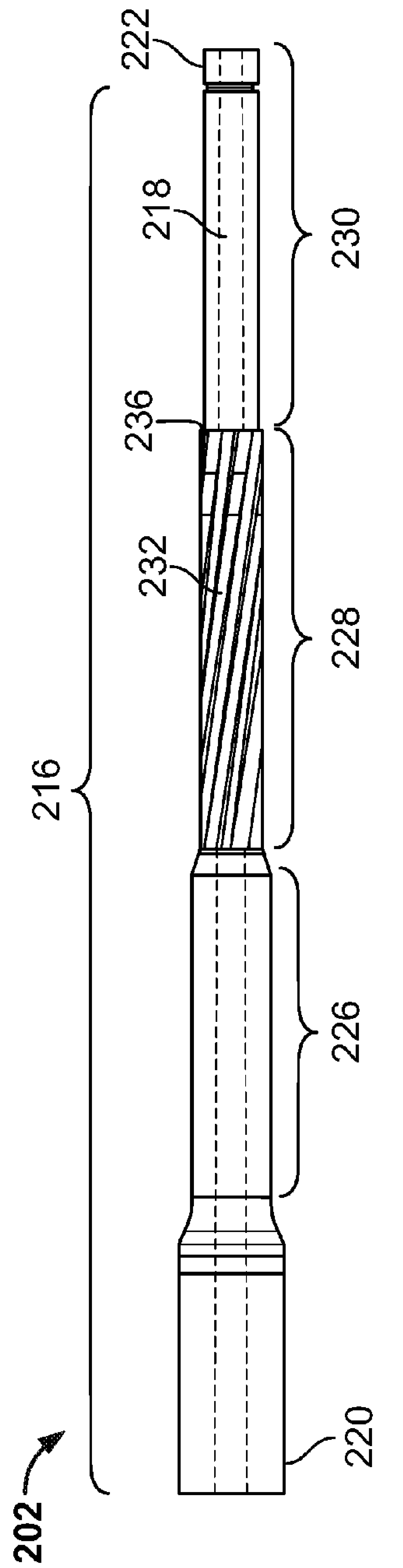
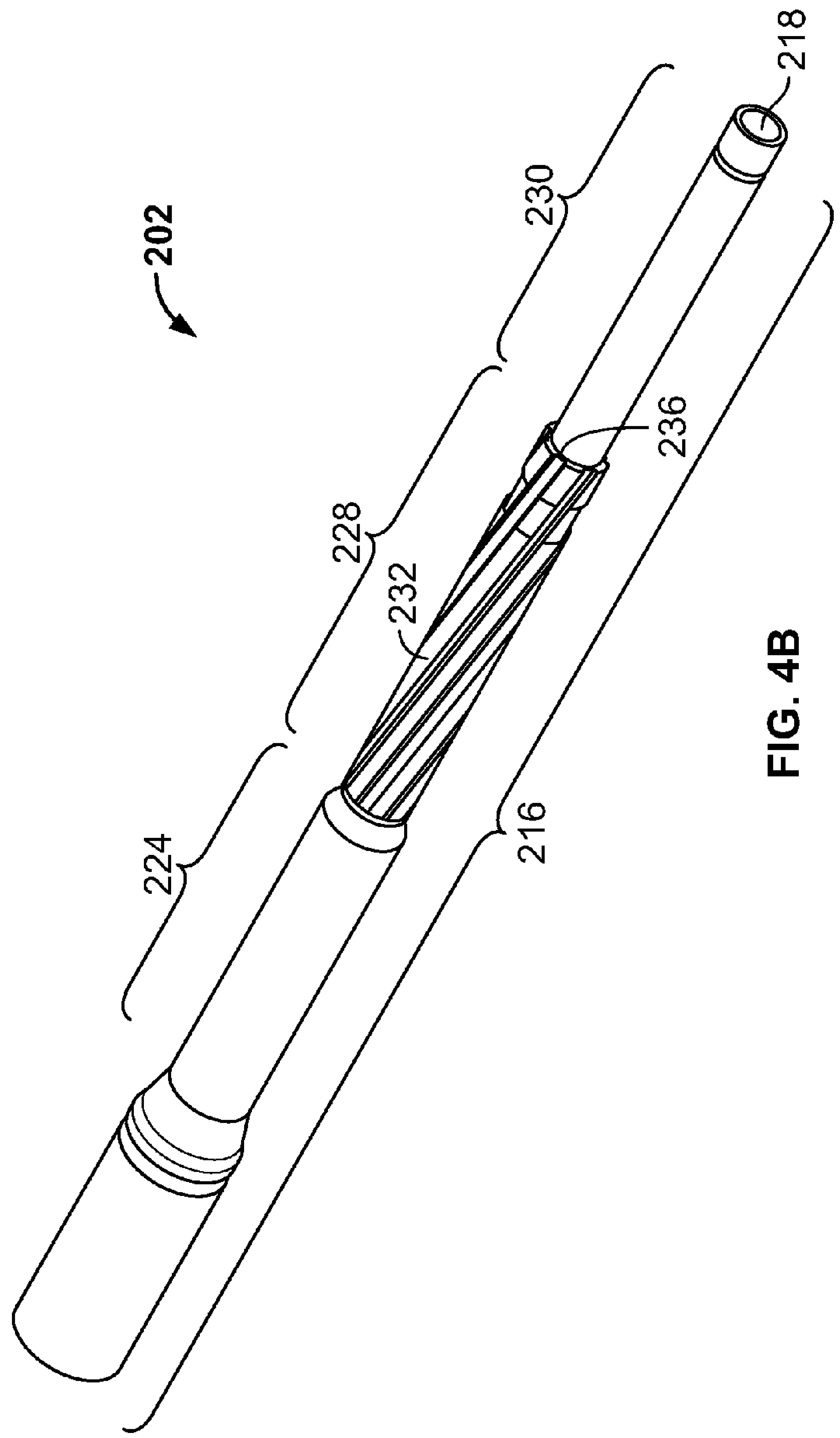


FIG. 3D



222
218
230
236
232
228
216
226
220
202

FIG. 4A



218
230
202
236
228
232
224
216

FIG. 4B

SHOCK TOOL FOR DRILLSTRING

CLAIM OF PRIORITY

This application is a U.S. National Stage of International Application No. PCT/US2013/071461, filed Nov. 22, 2013.

TECHNICAL FIELD

This specification generally relates to a tool and method for absorbing axial and torsional shock loads in a drilling string.

BACKGROUND

In connection with the recovery of hydrocarbons from the earth, wellbores are generally drilled using a variety of different methods and equipment. According to one common method, a roller cone bit or fixed cutter bit is rotated against the subsurface formation to form the wellbore. The drill bit is rotated in the wellbore through the rotation of a drill string attached to the drill bit and/or by the rotary force imparted to the drill bit by a subsurface drilling motor powered by the flow of drilling fluid down through the drill string and through the drilling motor.

Downhole vibrations and shocks (referred to collectively and/or interchangeably herein as "shock loads") are induced by interactions between the rotating bit and various types of hard rock and/or "sticky" earth formations at or near the floor of the wellbore. Shock loads induced at the drill bit are in turn transmitted to other components of the bottomhole assembly, as well as to the supporting drill string. Shock loads imparted on the drill string can diminish the life of its interconnected members by accelerating the process of fatigue. Additionally, excessive shock loads can cause spontaneous downhole equipment failure, wash-outs and a decrease in penetration rate.

Axial shock loads tend to cause a condition known as "bit bounce," where the drill bit momentarily lifts up and loses contact with the floor of the wellbore. Bit bounce is known to cause acute damage to bit cutters and supporting bearings. Torsional shock loads are often caused by a phenomenon known as "stick-slip." Stick-slip occurs when the drill bit stalls (e.g., drags or stops rotating completely) due to friction with the earth formations in the wellbore. When the drill bit stalls, typically, the attached drill string continues to turn, which can result in damage to the drill string and/or other components of the bottomhole assembly. Even if the operating torque applied through the drill string eventually succeeds in breaking the bit free of the formation, (i.e., overcoming the friction torque load on the bit resulting in a stall), the sudden release of the bit can cause it to rotate faster than the drill string. Stick-slip can cause problems in the operation of the drilling assembly and in the formation of the wellbore. In some cases, severe stick-slip can cause strong lateral vibrations in the drill string, which are also damaging.

Downhole shock loads are a major contributor to the failure of various components of the downhole equipment. Downhole shock loads may also cause damage to the wellbore itself (e.g., when lateral vibrations cause the drill string to contact the walls of the wellbore). Thus, mitigation of downhole shock loads is key to avoiding non-productive time and preventing equipment damage

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of an example drilling rig for drilling a wellbore.

FIG. **2**A is a half, side cross-sectional view of an example shock tool assembly.

FIG. **2**B is a half, perspective cross-sectional view of the shock tool assembly.

FIG. **3**A is a perspective view of a shock tool housing of the shock tool assembly of FIGS. **2**A and **2**B.

FIG. **3**B is half, perspective cross-sectional view of the shock tool housing.

FIG. **3**C is a top view of the shock tool housing.

FIG. **3**D is a half, side cross-sectional view of the shock tool housing, taken along the Section A-A marked in FIG. **3**C.

FIG. **4**A is a side view of a shock tool mandrel of the shock tool assembly of FIGS. **2**A and **2**B.

FIG. **4**B is a perspective view of the shock tool mandrel.

Many of the features are exaggerated to better show the features, process steps, and results. Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

FIG. **1** is a diagram of an example drilling rig **10** for drilling a wellbore **12**. The drilling rig **10** includes a drill string **14** supported by a derrick **16** positioned generally on an earth surface **18**. The drill string **14** extends from the derrick **16** into the wellbore **12**. The lower end portion of the drill string **14** includes at least one drill collar **20**, and in some implementations includes a subsurface drilling fluid-powered motor **22**, and a drill bit **24**. The drill bit **24** can be a fixed cutter bit, a roller cone bit, or any other type of bit suitable for drilling a wellbore. A drilling fluid supply system **26** circulates drilling fluid (often called "drilling mud") down through a bore of the drill string **14** for discharge through or near the drill bit **24** to assist in the drilling operations. The drilling fluid then flows back toward the surface **18** through an annulus **28** formed between the wellbore **12** and the drill string **14**.

The wellbore **12** can be drilled by rotating the drill string **14**, and therefore the drill bit **24**, using a rotary table or top drive, and/or by rotating the drill bit with rotary power supplied to the subsurface motor **22** by the circulating drilling fluid. A shock tool assembly **100** in accordance with one or more concepts of the present disclosure is positioned below the subsurface motor **22**. As described below, the shock tool assembly **100** absorbs both axial and torsional shock loads generated as the rotating drill bit **24** cuts through earth to create the wellbore **12**.

In the foregoing description of the drilling rig **10**, various items of equipment, such as pipes, valves, pumps, fasteners, fittings, etc., may have been omitted to simplify the description. However, those skilled in the art will realize that such conventional equipment can be employed as desired. Those skilled in the art will further appreciate that various components described are recited as illustrative for contextual purposes and do not limit the scope of this disclosure. Further, while the drilling rig **10** is shown in an arrangement that facilitates straight downhole drilling, it will be appreciated that directional drilling arrangements are also contemplated and therefore are within the scope of the present disclosure.

FIGS. **2**A and **2**B depict an example shock tool assembly **200** that can, for example, be incorporated in the drilling rig **10** as an extension of the drilling string **14** projecting into the wellbore **12**. As shown, the shock tool assembly **200** features an elongated tubular mandrel **202** and a collinear elongated tubular housing **204** that receives the mandrel **202** in a central bore. During operation of the drilling rig **10**, the mandrel **202** is driven (e.g., via its connection to the rotating drill string **14** or by the subsurface motor **22**) to rotate about a longitudinal centerline. The mandrel **202** is coupled to the housing **204** such that torque imparted on the rotationally driven mandrel is transferred to the housing, causing the housing to rotate together with the mandrel. When the shock tool assembly **200** is deployed in the drilling string **14**, the drill bit **24** is installed at the bottom end of the housing **204** and turns as the housing turns. As described in detail herein, the shock tool assembly **200** is designed to absorb both axial and torsional shock loads encountered by the drill bit **24** during the rotational drilling process.

In this example, the housing **204** is a multi-component sub-assembly, including a splined housing **204*a***, a spring housing **204*b***, and a piston housing **204*c***. The splined housing **204*a***, spring housing **204*b***, and piston housing **204*c*** are coupled to one another in an end-to-end configuration (e.g., by mating threads or by press fitting). The splined housing **204*a*** is positioned above spring housing **204*b***, which is positioned above the piston housing **204*c***. In other implementations one or more of the housings **204*a***, **204*b*** and **204*c*** may be formed as a single integral housing.

Note that use of terminology such as "above" and "below" to describe elements is for describing relative orientations of the various components of the assembly. For example, "above" used in this context means proximal to the beginning of the drill string (i.e., at the point where the drill string is connected to the drilling rig); and "below" means distal to the beginning of the drill string (or proximal to the end of the drill string, toward the floor of the wellbore). Unless otherwise stated explicitly, the use of such terminology does not imply a particular position or orientation of the assembly or any other components relative to the direction of the Earth gravitational force, or the Earth ground surface.

The mandrel **202** engages the splined housing **204*a*** via a mating set of helical splines and grooves. The mating splines and groove facilitate relative telescoping movement between the mandrel **202** and the housing **204**. Thus, the mandrel **202** and housing **204** are designed to move in combined rotation and axial motion relative to one another via the matching helical splines and grooves.

Turning now to FIGS. **3A-3D**, the splined housing **204*a*** includes a tubular body **206** having a central bore **208** for receiving a portion of the mandrel **202**. The upper portion of the bore **208** defines a plurality of sealing trenches **210**, which can be fitted with dynamic seals (e.g., dynamic O-ring seals) that engage an outer surface of the mandrel **202**. The lower portion of the bore **208** features a pattern of female multi-spiral spline grooves **212**. The spline grooves **212** are appropriately configured (e.g., in terms of number, size, shape, and pitch angle) to accommodate a matching pattern of male splines formed on the mandrel **202**. The lower portion of the splined housing **204*a*** defines a reduced-diameter coupling **214** for attaching the splined housing to the spring housing **204*b***. A port **215** is provided in the cylindrical side wall of the splined housing **204*a*** for introducing lubricant oil.

Turning next to FIGS. **4A** and **4B**, the mandrel **202** includes an elongated tubular body **216** having a central bore **218** for conveying drilling fluid from the drill sting **14** onward towards the drill bit **24**. The top end of the mandrel **202** defines a coupling **220** for connecting the mandrel to the drill string **14**. The bottom end of the mandrel **202** defines a coupling **222** for connecting the drill string to a wash pipe **224** (see FIGS. **2A** and **2B**). Between its top and bottom ends, the mandrel **202** defines a sealing portion **226**, a spline portion **228**, and a spring portion **230**.

The sealing portion **226** of the mandrel **202** is provided having a substantially smooth outer surface. The diameter of the sealing portion **226** closely mirrors that of the spline housing's central bore **208**, so that the dynamic seals located in the sealing trenches **210** bear against the smooth outer surface of the mandrel **202**. The spline portion **228** features a pattern of male, multi-spiral splines **232**. The male splines **232** are received by the female spline grooves **212** of the spline housing **204*a***, allowing the mandrel **202** to move telescopically and rotationally through the housing **204**.

Similar to the sealing portion **226**, the spring portion **230** exhibits a substantially uniform or smooth outer surface (i.e., a surface without splines). The diameter of the spring portion **230** is significantly less than that of the spline portion **228**, so as to form an annulus between the outer surface of the mandrel and the inner surface of the spring housing's central bore. The annulus is designed to accommodate a resilient member **234** (see FIGS. **2A** and **2B**). The abrupt transition between the spline portion **228** and the reduced-diameter spring portion **230** creates the shoulder **236** for positioning the top end of the resilient member **234**.

Referring back to FIGS. **2A** and **2B**, the spring housing **204*b*** is positioned below the splined housing **204*a***. The spring housing **204*b*** receives the spring portion **230** of the mandrel **202**, below the helical splines **232**, with the resilient member **234** located in the annulus and situated between the radially protruding shoulder **236** of the mandrel **202** and a rim **238** at the upper end of the piston housing **204*c***.

In this example, the resilient member **234** includes an arrangement of disc springs, e.g., Bellville discs. The resilient member **234** is designed to preload under WOB (Weight on Bit) and torque-transfer loads. Additional deflection beyond this initial preloading accommodates one or both of axial and torsional shock loads. The preload creates a biasing force in the resilient member **234** urging the mandrel **202** outwardly through the upper end of the spline housing **204*a***. The number of disc springs, the characteristics of the individual disc springs (e.g., spring force, static loading limit, dynamic loading limit, etc.), and the configuration of the arrangement (e.g., series or parallel) can be selected so as to provide the resilient member with appropriate performance properties. In some examples, the resilient member is designed to preload up to about 8% under WOB. In some examples, the resilient member is designed to preload up to about 15% under torque transfer conditions.

The piston housing **204*c*** is positioned below the spring housing **204*b***. As noted above, the piston housing's rim **238** supports the lower end of the resilient member **234**. The wash pipe **224** is coupled to the end of the mandrel **202** and projects downward into the central bore of the piston housing **204*c***. The bore **240** of the wash pipe **224** is aligned with the bore **218** of the mandrel **202**, allowing drilling fluid to pass from the mandrel to the wash pipe. A balance piston **242** is located in an annulus between the outer surface of the wash pipe **224** and the inner surface of the central bore of the piston housing **204*c***. The balance piston **242** is designed to balance the pressure the lubricant oil with the pressure of the drilling fluid. The piston housing **204*c***, at its lower end, provides a coupling **244** for attaching directly or via other downhole equipment to the drill bit **24**.

As noted above, the mandrel **202** is coupled to the housing **204** such that torque imparted on the rotationally driven mandrel is transferred to the housing, causing the housing to rotate together with the mandrel. This arrangement is permitted by cooperation between the mating splines **232** and grooves **212** together with the resilient member **234**. The spiral nature of the splines **232** and grooves **212** tends to urge the mandrel **202** to rotationally and telescopically move through the housing **204** as the mandrel is rotated. However, the resilient member **234** is located between the housing **204** and the mandrel **202** and therefore resists the relative telescopic movement. When further movement of the mandrel **202** is prevented by spring force of the resilient member **234**, the mandrel's splines **232** bear against the spline housing's grooves **212**, resulting in a transfer of torque from the rotationally driven mandrel to the housing. The resilient member **234** is designed to preload under the force of the mandrel **202** bearing downward as it is rotated and urged through the housing **204**.

Axial and torsional shock loads encountered by the drill bit **24** are imparted on the housing **204**, urging the housing to move rotationally and telescopically relative to the rotating mandrel **202**. This movement of the housing **204** relative to the mandrel **202**, causing the housing to "ride up" the splines **232** of the mandrel, compressing the resilient member **234**, which is positioned to resist the relative movement. Thus, the shock loads are absorbed by compression of the resilient member **234**. Small axial and torsional vibrations and nominal shocks are also damped out by the resilient action of the resilient member **234**. Larger excitements are damped out by the lubricant oil acting on the balance piston **242**. For example, when the resilient member **234** compresses due to shock, the volume holding the lubricant oil is reduced, which in turn increases the oil pressure. The oil pressure increase causes the balance piston **242** to move downward to restore a pressure balance.

Characteristics of the helical splines **232** and grooves **212** are selected so as to balance the need to manage both torsional and axial shock loads encountered by the drill bit **24** with a single shock tool. This goal is accomplished, for example, in the illustrated embodiment where the geometry of the splines and grooves is a mult-start helical pattern having a pitch angle of about nine degrees measured from a longitudinal axis of the tool, with the splines and grooves exhibiting a rectangular cross-section. In some examples, the pitch angle is between about five and sixty degrees. As the pitch angle increases in severity, the shock tool is able to accommodate more torsional shock and less axial shock. Conversely, as the pitch angle decreases, the shock tool is able to accommodate more axial shock and less torsional shock. Creating a pitch angle of about twenty-two degrees provides substantial equal response to either axial or torsional shock loads. Thus, the pitch angle can be optimized for the expected drilling conditions. If more axial shock is expected verses torsional shock, then the pitch angle used can be less than twenty-two degrees, and vice versa.

In some implementations, the multi-spline arrangement described in the shock tool assembly **200** provides superior strength and wear resistance compared to a single spline. For example, the shear stress acting on the splines during operation of the shock tool is distributed evenly over the multiple splines, thereby reducing the stress in each individual spline.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the inventions.

What is claimed:

1. A shock tool for a drill string positionable in a wellbore, said shock tool comprising:

an outer tubular housing having female multi-spiral helical spline grooves disposed on an interior surface of the housing, said housing including a lower connector for coupling to a spring housing; and

an inner tubular mandrel having a portion of an exterior circumferential surface with male multi-spiral helical splines configured to mate with the female multi-spiral helical grooves of the outer tubular housing and at least a lower portion of the exterior circumferential surface of the mandrel not containing splines thereon, said inner tubular mandrel telescopically and rotationally received in the outer tubular housing with the male splines received in the female spline grooves of the outer tubular housing, said lower portion of the inner tubular mandrel without splines being received in the spring housing coupled to the outer tubular housing, said inner tubular mandrel having an axial fluid passageway for passage of drilling fluid supplied by the drill string through the mandrel,

wherein said spring housing includes at least one disc spring disposed around the lower portion of the exterior surface of the mandrel not containing splines thereon and in an annulus between the mandrel and an inner surface of the spring housing, said disc spring having a predetermined biasing force that biases at least a portion of the mandrel outwardly through an axial opening in an upper end of the outer tubular housing.

2. The shock tool of claim **1**, wherein the multi-spiral helical splines of the inner tubular mandrel have a pitch of between 5 degrees and 60 degrees measured from a longitudinal axis of the tool.

3. The shock tool of claim **2**, wherein the multi-spiral helical splines of the inner tubular mandrel have a pitch of about 9 degrees from the longitudinal axis.

4. The shock tool of claim **2**, wherein the multi-spiral helical splines of the inner tubular mandrel have a pitch of about 22 degrees from the longitudinal axis.

5. The shock tool of claim **1**, wherein the disc spring positioned inside the spring housing is biased with a preload of WOB (Weight on Bit) and torque transfer.

6. The shock tool of claim **5**, wherein the disc spring is biased at about 8% under WOB.

7. The shock tool of claim **5**, wherein the disc spring is biased at about 15% under torque transfer.

8. The shock tool of claim **1**, further comprising a balance piston located to facilitate dampening of axial and torsional shock loads absorbed by the disc spring.

9. The shock tool of claim **8**, further comprising a piston housing coupled to the spring housing, the balance piston located in an annulus between the mandrel and the piston housing.

10. The shock tool of claim **8**, further comprising lubricant oil contained in a space adjacent the balance piston, wherein a volume of the space decreases with compression of the disc spring.

11. The shock tool of claim **10**, wherein the outer tubular housing is sealed against the mandrel to contain the lubricant oil.

12. The shock tool of claim **1**, further comprising a wash pipe comprising a central bore aligned with the axial fluid passageway of the mandrel.

13. The shock tool of claim **12**, wherein a change in diameter of the mandrel between the lower portion of the exterior circumferential surface of the mandrel not containing splines and the portion of the mandrel having the splines creates a shoulder abutting one end of the disc spring.

14. The shock tool of claim **1**, wherein the lower portion of the exterior circumferential surface of the mandrel not containing splines comprises a smaller diameter than the portion of the mandrel having the splines.

15. A method of absorbing axial and torsional shock loads on a drill sting positioned in a wellbore, said method comprising:

installing a shock tool in a drill string, said shock tool including an outer tubular housing having a plurality of female multi-spiral helical spline grooves disposed on an interior surface of the housing, an inner tubular mandrel having a portion of an exterior circumferential surface with male multi-spiral helical splines configured to mate with the female multi-spiral helical grooves of the outer tubular housing and at least a lower portion of the exterior circumferential surface of the mandrel not containing splines thereon, said mandrel positioned in the outer housing with the male splines received in the female spline grooves of the housing, said lower portion of the mandrel without splines being received in a spring housing coupled to the outer tubular housing, wherein said spring housing includes at least one disc spring disposed around the lower portion of the exterior surface of the mandrel not containing splines thereon and in an annulus between the mandrel and an inner surface of the spring housing, said disc spring having a predetermined biasing force that biases at least a portion of the mandrel outwardly through an axial opening in an upper end of the outer tubular housing;

conducting drilling operations with the drill string and shock tool positioned in the wellbore;

receiving axial and torsional shock loads on a drill bit coupled to the shock tool;

rotating the outer tubular housing relative to the inner tubular mandrel in response to the axial and torsional shock loads;

translating rotary motion of the inner tubular mandrel into axial movement of the inner tubular mandrel inwardly into the outer tubular housing via the axial opening in the upper end of the outer tubular housing due to rotational movement of the male splines of the inner tubular mandrel received in the female spline grooves in the outer tubular housing; and

compressing the disc spring due to inwardly axial motion of the inner tubular mandrel, thereby absorbing the torsional and axial shock loads imposed on the drill string.

16. The method of claim **15**, further comprising dampening torsional and axial shock loads absorbed by the disc spring via a balance piston reacting to lubricant oil pressure.

17. The method of claim **16**, wherein the lubricant oil is contained in a space adjacent the balance piston, wherein a volume of the space decreases with compression of the disc spring.

18. The method of claim **15**, wherein the multi-spiral helical splines of the inner tubular mandrel have a pitch of between 5 degrees and 60 degrees measured from a longitudinal axis of the tool.

19. The method of claim **18**, wherein the multi-spiral helical splines of the inner tubular mandrel have a pitch of about 9 degrees from the longitudinal axis.

20. The method of claim **15**, wherein the disc spring positioned inside the spring housing is biased with a preload of WOB (Weight on Bit) and torque transfer.

21. A shock tool for a drill string positionable in a wellbore, said shock tool comprising:

an outer tubular housing having female multi-spiral helical spline grooves disposed on an interior surface of the housing; and

an inner tubular mandrel having a portion of an exterior circumferential surface with male multi-spiral helical splines configured to mate with the female multi-spiral helical grooves of the outer tubular housing and at least a lower portion of the exterior circumferential surface of the mandrel not containing splines thereon, said inner tubular mandrel telescopically and rotationally received in the outer tubular housing with the male splines received in the female spline grooves of the outer tubular housing, said lower portion of the inner tubular mandrel without splines being received in a spring housing portion of the outer tubular housing, said inner tubular mandrel having an axial fluid passageway for passage of drilling fluid supplied by the drill string through the mandrel,

wherein said spring housing portion of the outer tubular housing includes at least one disc spring disposed around the lower portion of the exterior surface of the mandrel not containing splines thereon and in an annulus between the mandrel and an inner surface of the spring housing portion of the outer tubular housing, said disc spring having a predetermined biasing force that biases at least a portion of the mandrel outwardly through an axial opening in an upper end of the outer tubular housing.

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